B2 cont'd

value proportionate to the square of the reciprocal of the gear reduction ratio of the worm gear mechanism, lowering inertia of the rotor provides a comfortable steering touch or feel. In contrast, in the synchronous motor disclosed in Japanese Patent No. 2,967,340, the yoke has a large diameter due to the inherent structure of the permanent magnet type synchronous motor, thus limiting reduction in inertia of the rotor.--

Please replace the paragraph beginning at page 5, line 7, with the following rewritten paragraph:

B3

--The electric motor of the usual type includes the armature windings distributed and wound in more than two slots, with a relatively large portion of the armature windings having no contribution to formation of effective magnetic flux with resultant increased copper losses. Consequently, the electric motor should undergo further considerable research and development in order to provide an increased power output.--

Please replace the paragraph beginning at page 10, line 5, with the following rewritten paragraph:

B4

--The steering torque sensor 70 includes an excitation coil 71 formed in a substantially 8-shaped profile, and a detection coil 72 formed in a substantially 8-shaped profile and dimensioned in the same size as the excitation coil 71. The excitation coil 71 and the detection coil 72 intersect one another at a substantially right angle in concentric relation, thereby forming one set of magnetic heads 73 which are located in close proximity to an outer periphery of the pinion shaft 32. In particular, the excitation coil 71 formed in the 8-shaped profile is mounted on the outer periphery of the pinion shaft 32, and the detection coil 72 formed in 8-shaped profile is overlapped on the excitation coil 71 at an angle shifted 90 degrees in phase. During this assembling operation, the linear portion of the 8-shaped profile of the excitation coil 71 is placed on the outer periphery of the pinion shaft 32 substantially parallel to the outer periphery of the pinion shaft 32 or substantially parallel to a longitudinal axis of the pinion shaft 32. Reference numeral 74 designates a source of excitation voltage for applying an excitation voltage to the excitation coil 71. Reference numeral 75 designates a voltage amplifier.--

Please replace the paragraph beginning at page 14, line 26 to page 15, line 6, with the following rewritten paragraph:

B5

--The reduction gear mechanism 120 functions as a torque delivery unit which transmits the steering assist torque, produced by the electric motor 80, to the pinion shaft 32 and includes a worm gear mechanism. In particular, the gear reduction unit 120 includes a worm shaft 121 coupled to the motor shaft 87 of the electric motor 80 via the torque limiter 110, a worm 122 formed on an outer periphery of the worm shaft 121, and a worm wheel 123 (hereinafter referred to merely as a wheel) coupled to the pinion shaft 32.--

Please replace the paragraphs beginning at page 21, line 13 to page 23, line 16, with the following rewritten paragraphs:

B6 cont.

--The number of cogging times produced per each revolution of the rotor 86 equals to a value corresponding to the least common multiple between the number of the salient poles 92a to 92i (the number of the poles defined by the stator windings 93a to 93i) and the number of the permanent magnets 94a to 94h. However, it has been found that, as the least common multiple increases, the cogging effect is reduced. In order to increase the least common multiple with a view to reducing the cogging effect, it is a good practice to increase the number of the permanent magnet poles 94a to 94h and the number of the poles of the stator windings 93a to 93i.

Since the electric power steering apparatus 10 should be incorporated in a narrow space in the motor vehicle, the electric power steering apparatus 10 should have small size in structure. To this end, the electric motor 80 should also be small in size. Further, the electric motor 80 of the electric power steering apparatus 10 should have a high power output. For example, in actual practice, the electric motor with a diameter of about 50 to 70 mm is employed and is applied with electric current of about 30 to 40 amperes. Since the electric motor 80 is thus small in size, a large number of stator windings 93a to 93i may be desirably arranged on an area outwardly of the rotor 86.

Since the electric motor 80 is a DC brushless motor, it is usual practice to drive the stator windings 93a to 93i with three-phase electric power. The second outer stator 84 may have three poles or the number of pole pieces equal to a multiple of three.

In addition, since the electric power steering apparatus 10 provides the steering assist torque in a frequent and suitable manner in dependence on the steering torque exerted by the steering wheel, inertia of the rotor 86 of the electric motor 80 must be reduced to a level as small

B6 Cont'd

as possible. Lowering inertia provides for an improved comfortable steering touch. In order to lower inertia of the rotor 86, the rotor 86 may be light in weight and small in diameter.

In review, in order to employ the electric motor 80 in the electric power steering apparatus 10, a first condition must be met to allow the electric power steering apparatus 10 to be small in size to overcome the limited mounting space in the motor vehicle, and a second condition must also be met to allow the rotor 86, having the permanent magnets, to be reduced in outer diameter with a view to lowering inertia while allowing the stator, having the stator windings, to form the outer stator 85.

The presence of the inner rotor 86 formed with the N and S poles of the permanent magnets 94a to 94i alternately arranged in the circumferential direction essentially provides the number of two poles or the number of pole pieces equivalent to a multiple of two.

As previously noted above, the outer diameter of the inner rotor 86 is determined by taking the limited mounting space of the electric motor 80 in the electric power steering apparatus 10 and the required low inertia into consideration. If, however, the inner rotor has a smaller diameter than is required, it is difficult to increase the number of poles of the permanent magnets 94a to 94h. In order to provide a comfortable steering touch or feeling of the electric power steering apparatus 10, an allowable range of inertia must be initially considered whereupon the diameter of the inner rotor must be preferably addressed.--

Please replace the paragraphs beginning at page 23, line 27 to page 25, line 17, with the following rewritten paragraphs:

B7 Cont.

--In summary, according to the present invention, the diameter of the inner rotor 86 is determined first to allow the inner rotor 86 to have permanent magnets 94a to 94h with eight poles with a view to improving the cogging performance for thereby providing comfortable steering touch, second to allow the electric motor 80 to be small-sized with a view to meeting the limited mounting space of the motor vehicle, and third to allow the inner rotor to have low inertia in a range permitted for obtaining the comfortable steering touch.

With such an inner rotor 86 determined to have permanent magnets 94a to 94h with eight poles, in order to comparatively increase the least common multiple between the number of poles of the permanent magnets 94a to 94h and the number of the stator windings 93a to 93i, the stator is designed to have nine poles of the stator windings 93a to 93i (i.e., nine salient poles 92a to 92i

B7 Conc'd.

or nine slots). As a result, the least common multiple is 72. Although it is possible for the stator windings 93a to 93i to have more than nine poles, an increase in the number of poles of the stator windings is reflected by an adverse effect on the production cost.

Now, the relationship between the number of poles of the stator windings 93a to 93i of the electric motor 80 and the number of poles of the permanent magnets 94a to 94h, and the smoothness of the steering wheel is described below with reference to the graph of FIG. 10.

When the inner rotor 86 has less than six poles and the number of poles of the stator windings 93a to 93i corresponds to a multiple of three and is less than fifteen, the least common multiple between the number of poles of the permanent magnets 94a to 94h and the number of poles of the stator windings 93a to 93h becomes relatively small.

On the contrary, when the inner rotor 86 has eight poles and the number of poles of the stator windings corresponds to a multiple of three and is less than fifteen, the least common multiple between the number of poles of the permanent magnets 94a to 94h and the number of poles of the stator windings 93a to 93h becomes relatively large. In particular, when the inner rotor has eight poles and the stator windings 93a to 93i have nine poles, the least common multiple becomes 72 and is larger than the other combination. As the least common multiple increases, the cogging effect decreases. As a result, the cogging effect of the electric motor 80 exerted on the steering wheel decreases, thereby providing steering smoothness in the steering wheel 11 as viewed in FIG. 10. For this reason, the electric power steering apparatus 10 is able to cause the steering wheel 11 to provide a comfortable steering touch or feeling to the vehicle driver.--

Please replace the paragraph beginning at page 28, line 12, with the following rewritten paragraph:

B8

--Further, since the electric motor is constructed having an annular outer stator and an inner rotor located in the outer stator, inertia of the inner rotor can be minimized, providing an improved steering touch or feeling to the steering handle. Also, the presence of a combined structure of the outer stator and the inner rotor allows the electric motor to be small in size, permitting the whole structure of the electric power steering apparatus to be small in size to suit for narrow mounting space in the motor vehicle.--